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# DESIGN AND DEVELOPMENT OF PORTABLE MODIFIED ATMOSPHERIC PACKAGING (MAP) UNIT FOR GRAIN DISINFESTATION

**ARCHANA Y KALAL[1], ANANDAKUMAR[2], AMBRISH GANACHARI[3] & PRASANNA GUDI[4]**

[1, 2, 4] *Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka, India*

[3] *Assistant Professor, Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka, India*

***ABSTRACT***

***A portable modified atmospheric packaging (MAP) unit was designed and developed keeping in view the needs of small farmers and entrepreneurs for safe storage of their agricultural produce. The MAP unit consists of grain holding unit fitted with sealing unit, nozzle, pressure regulator and control panel, solenoid valve with timer all placed over the working table and connected to the carbon dioxide cylinder. The dimensions of the unit were 600, 450 and 200 mm in length, width and height respectively. The nozzle of 2 mm orifice diameter was used for flushing gas into the packet with grains. The operational parameters of the unit viz., flushing pressure and time were optimized for three different grains (i.e., rice, pigeon pea and foxtail millet) of one kg capacity each using the statistical software. The flushing pressure of 3 kg/cm$^2$ for a period of 5 s was found to flush maximum amount of $CO_2$ (89.9%) and minimum amount of $O_2$ (0.06%) concentrations into the packets for all the grains. The estimated cost of the developed portable modified atmospheric packaging unit was found to be Rs 8350.00 and the cost of packaging was worked out to be Rs 2.00 per packet of one kg each.***

***KEYWORDS: Modified Atmospheric Packaging, Grain Disinfection, Flushing Pressure and Flushing Time***

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**Original Article**

## INTRODUCTION

Agriculture is an important sector of Indian economy as it contributes about 17% to the total GDP. The food grains production has increased upto 252.56 MT during 2011-12 highest ever since independence. In India, annual storage losses have been estimated to be about 14 MT of food grains worth of Rs. 7,000 crore every year in which insects alone accounts for nearly Rs. 1,300 crores. A major cause for stored grain deterioration and degradation are insect, pest and micro-organisms which results in both quantitative as well as qualitative losses. It is estimated that about 60-70% of food grain produced in the country is stored in indigenous storage structures like Kanaja, Kothi, Sanduka and earthern pots which are not suitable for storing grains for longer periods.

Grain storage plays an important role in preventing losses which are caused mainly due to weevils, beetles, moths and rodents (Kartikeyan *et al*, 2009). The earlier studies have shown that modified atmospheric storage of grains with higher levels of carbon dioxide and lower levels of oxygen is an effective method against insects, pests and micro-organisms. The lower level of oxygen in modified atmospheric storage reduces the respiration rate of seeds and activity of insects and micro-organisms within the storage. MAP is the replacement of air in a pack with a single gas or mixture of gases where the proportion of each component is fixed before introducing into the pack.

MAP techniques are also widely used for a range of fresh or chilled foods including raw and cooked meats and poultry, fish, fresh pasta, fruits and vegetables and more recently coffee, tea and bakery products.

## MATERIALS AND METHODS

As the existing modified atmospheric packaging units are costly therefore an attempt is made to develop a small scale portable modified atmospheric packaging unit.

### Design of Modified Atmospheric Packaging Unit

### Grain Holding Unit

The dimensions of grain holding unit were optimized based on the length of the sealing unit and packaging materials of different sizes. It was made of 8 mm thick plywood (soft) material with good durability and ease to handle. The dimensions of the unit were 600, 450 and 200 mm in length, width and height respectively.

### Top Cover

The top cover of the MAP unit was made of 5 mm thick transparent fiber sheet to ensure proper functioning inside the unit.

### Sealing Unit

The sealing machine was selected based on dimensions of packaging material. The sealing unit of SEPACK brand, manufactured by SEVANA Traders and Service Pvt Ltd., Cochin was used.

### Nozzle

The nozzle of about 2 mm orifice diameter, made of copper was used for flushing the gases into the packaging materials.

### Pressure Regulator

The pressure regulator was provided to regulate the gas flow pressure. The specifications of regulator were model OR Mini (1/4’), Pressure (Max) P1–16 kg/cm$^2$, (Min) P2–12 kg/cm$^2$ and Gauge pressure of 0-16 kg/cm$^2$.

### Solenoid Value with Timer

Timer controlled solenoid valve was normally of closed type used for automatic and accurate control of the gas flow into the packaging materials.

### Working Table

The whole MAP unit was placed on a portable working table made of cast iron angles. The dimensions of the table were 620, 470 and 850 mm in length, width and height respectively. These dimensions were fixed based on the ergonomics of the operator to ensure comfort working during its operation.

### Carbon Dioxide Cylinder

The commercially available carbon dioxide cylinder was used for the research work. The gas cylinder was about 47.4 m$^3$ of capacity with its dimensions of 455 mm and 200 mm of height and diameter respectively.

**Packaging Materials**

The polypropylene (PP) packaging materials were used for packing of food grains for their high transparency. The sizes of bags were decided based on the volume of food grains and the head space required for filling the gases. The sizes finalized were 1 kg capacity of 203 mm × 304 mm (L×W) dimensions.

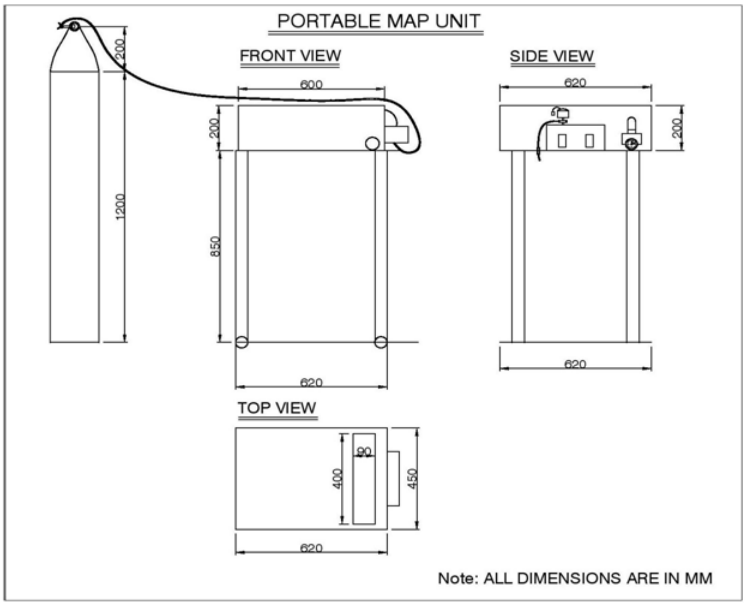


**Figure 1: Schematic Diagram of Modified Atmospheric Packaging (MAP) Unit**

**Optimization of $CO_2$ Flushing Pressure and Time for Selected Grains**

The gas was flushed inside the packaging material at specified pressure and time to fill maximum $CO_2$ concentration inside the packet. The target gas concentrations for insect toxicity were 3% or less of $O_2$ and 60% or more of $CO_2$ (Mbata *et al.,* 2004). Different pressure and time combinations were selected to achieve the target composition and interaction of both parameters were taken into consideration for optimization process.

**$CO_2$ Flushing Pressure**

The flushing was carried out at three different pressures *viz*., 2, 3 and 4 kg/cm$^2$ so that maximum filling of carbon dioxide is achieved without spillover of grains from the packaging material.

**$CO_2$ Flushing Time**

The flushing time increased the volume flow of carbon dioxide. Three different time intervals *viz*., 5, 10 and 15 s were selected based on preliminary study to flush the gas inside 1 kg packaging material to obtain the required composition inside the packet.

**Statistical Analysis**

Statistical analysis was carried out to study the effect of different parameters on all the dependent variables by Asymmetric General Factorial Design (GFD). Two independent factors *viz.,* flushing pressure and time were used at three levels each. The different treatments combinations are given in Table 1.

**Table 1: Treatment Combinations of Independent Factors**

| Treatments | Combination Factors |
|---|---|
| A1B1 | Pressure 2 kg/cm$^2$ and time 5 s |
| A1B2 | Pressure 2 kg/cm$^2$ and time 10 s |
| A1B3 | Pressure 2 kg/cm$^2$ and time 15 s |
| A2B1 | Pressure 3 kg/cm$^2$ and time 5 s |
| A2B2 | Pressure 3 kg/cm$^2$ and time 10 s |
| A2B3 | Pressure 3 kg/cm$^2$ and time 15 s |
| A3B1 | Pressure 4 kg/cm$^2$ and time 5 s |
| A3B2 | Pressure 4 kg/cm$^2$ and time 10 s |
| A3B3 | Pressure 4 kg/cm$^2$ and time 15 s |

Analyses of variance (ANOVA) were conducted to determine whether significant effect exists of the filling pressure and filling time on the gas composition. The optimization was carried using the optimization tool of the statistical software with two responses in the range.

**Responses**

R1 – $CO_2$ maximization >60 %

R2 - $O_2$ minimization <3 %

**Economics of Developed Unit**

The cost of newly developed modified atmospheric packaging unit was estimated by considering cost of machine box and basic prices of cover, sealing unit, nozzle, solenoid value, pressure regulator, control panel, working table, $CO_2$ cylinder. The cost of operation was calculated by considering fixed cost and variable cost.

## RESULTS AND DISSCUSSIONS

### Optimization of $CO_2$ Flushing Pressure and Time for Selected Grains

The flushing of carbon dioxide was carried out at three different flushing pressures and time intervals. The gas composition of package changed with change in flushing time and pressure along with grain parameters. The data were analyzed using statistical analysis and flushing pressure and time for each grain was optimized for 1 kg retail packets.

### Optimization of Flushing Pressure and Time for Rice

The flushing of carbon dioxide was carried out at three different pressure and time intervals. The data recorded for the composition inside the packet are presented in the Table 2.

The data was statistically analyzed and it showed that flushing pressure and time have significant effect on concentration of flushed gas inside the packet. The effect of flushing pressure and time on retention of $CO_2$ and $O_2$ are graphically represented in Figure 2 and Figure 3 respectively. The optimization process was carried out with the optimization tool by fixing the responses R1 ($CO_2$) and R2 ($O_2$) in range. The flushing of $CO_2$ gas at 3 kg/cm$^2$ pressure for 5shaving 100 per cent desirability was optimized followed by 2 kg/cm$^2$ pressure with 10 s of flushing $CO_2$ gas for one kg rice retail packets.

**Table 2: Concentrations of $CO_2$ and $O_2$ at Different Flushing Pressure for One Kg Rice Packet**

| | 2 kg/cm² | | | | | | 3 kg/cm² | | | | | | 4 kg/cm² | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | |
| | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ |
| 1. | 60.3 | 6.97 | 76.6 | 2.50 | 86.5 | 0.94 | 82.7 | 2.40 | 91.6 | 0.60 | 88.6 | 1.29 | 74.9 | 4.09 | 75.3 | 3.36 | 85.6 | 1.70 |
| 2. | 55.6 | 7.77 | 79.7 | 2.40 | 88.1 | 0.63 | 81.2 | 2.77 | 89.6 | 0.84 | 92.8 | 0.35 | 71.6 | 4.70 | 60.3 | 6.76 | 91.3 | 0.67 |
| 3. | 62.4 | 6.18 | 79.9 | 2.45 | 90.8 | 0.83 | 82.2 | 2.52 | 93.1 | 0.19 | 89.3 | 1.18 | 74.8 | 4.08 | 63.1 | 6.3 | 85.9 | 1.98 |
| Mean | 19.81 | 2.32 | 26.24 | 0.81 | 29.4 | 0.26 | 27.34 | 0.85 | 30.47 | 0.18 | 30.07 | 0.31 | 24.58 | 1.43 | 22.07 | 1.82 | 29.20 | 0.48 |
| CV % | 3.48 | 3.54 | 3.48 | 3.45 | 3.48 | 3.48 | 3.46 | 3.52 | 3.47 | 5.01 | 3.47 | 4.49 | 3.46 | 3.52 | 3.45 | 3.92 | 3.48 | 4.42 |
| CD@ 1% | 2.67 | 0.32 | 3.56 | 0.12 | 4.00 | 0.04 | 3.69 | 0.12 | 4.11 | 0.03 | 4.08 | 0.04 | 3.31 | 0.20 | 2.92 | 0.27 | 3.69 | 0.07 |

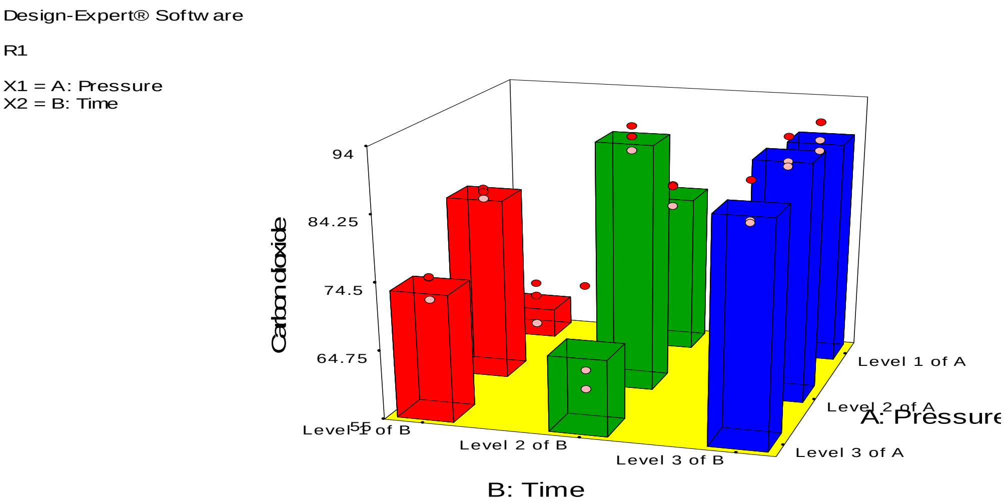


**Figure 2: Effect of Flushing Pressure and Flushing Time on Retention of $CO_2$ In One Kg Rice Packets**

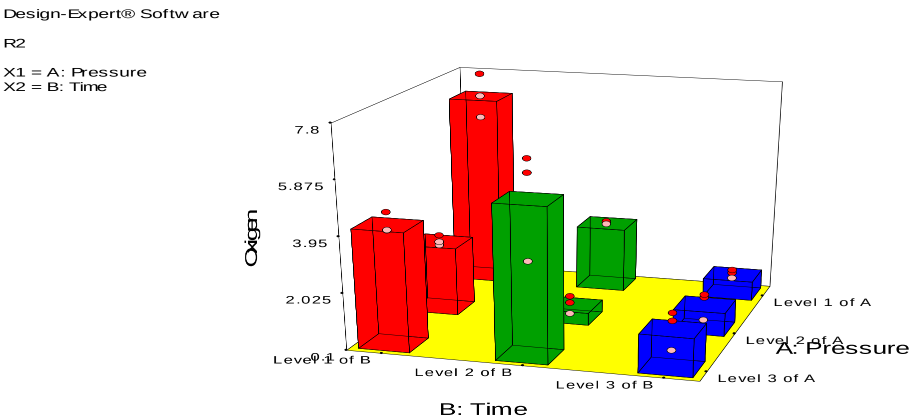


**Figure 3: Effect of Flushing Pressure and Flushing Time on Retention of $O_2$ in One Kg Rice Packets**

**Optimization of Flushing Pressure and Time for Pigeon Pea**

The flushing of carbon dioxide was carried at three different pressure and time intervals. The data recorded for the composition inside the packet was presented in the Table 3.

The data was statistically analyzed and it showed that flushing pressure and time have significant effect on concentration of flushed gas inside the packet. The effect of flushing pressure and time on retention of $CO_2$ and $O_2$ are graphically represented in Figure 4 and Figure 5 respectively. The optimization process was carried out with the optimization tool by fixing the responses R1 ($CO_2$) and R2 ($O_2$) in range. The flushing of $CO_2$ gas at 3 kg/cm$^2$ pressure for

5s having 100 per cent desirability was optimized followed by 2 kg/cm$^2$ pressure with 10 seconds of flushing gas for one kg pigeon pea retail packets.

**Table 3: Concentrations of $CO_2$ and $O_2$ at Different Flushing Pressure for One Kg Pigeon Pea Packet**

| | 2 kg/cm$^2$ | | | | | | 3 kg/cm$^2$ | | | | | | 4 kg/cm$^2$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | |
| | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ |
| 1. | 74.4 | 3.30 | 90.1 | 0.98 | 89.2 | 1.24 | 86.6 | 1.59 | 93.3 | 0.35 | 91.5 | 0.637 | 86.7 | 1.83 | 92.4 | 0.53 | 94.5 | 0.16 |
| 2. | 74.9 | 3.38 | 90.7 | 0.90 | 87.5 | 1.36 | 85.6 | 1.69 | 93.0 | 0.33 | 93.4 | 0.380 | 89.6 | 1.06 | 93.8 | 0.25 | 94.0 | 0.22 |
| 3. | 75.3 | 3.35 | 88.5 | 1.44 | 86.5 | 1.46 | 89.9 | 0.87 | 91.1 | 0.80 | 93.2 | 0.424 | 90.2 | 0.993 | 94.1 | 0.18 | 93.6 | 0.34 |
| Mean | 24.95 | 1.11 | 29.92 | 0.36 | 29.24 | 0.45 | 29.12 | 0.46 | 30.82 | 0.16 | 30.90 | 0.16 | 29.61 | 0.43 | 31.14 | 0.10 | 31.34 | 0.08 |
| CV % | 3.47 | 3.46 | 3.46 | 3.85 | 3.46 | 3.49 | 3.47 | 3.92 | 3.46 | 4.80 | 3.47 | 3.50 | 3.48 | 3.63 | 3.47 | 4.00 | 3.46 | 4.24 |
| CD@1 % | 3.37 | 0.15 | 4.04 | 0.05 | 3.94 | 0.06 | 3.94 | 0.06 | 4.16 | 0.03 | 4.18 | 0.02 | 4.01 | 0.06 | 4.21 | 0.01 | 4.22 | 0.01 |

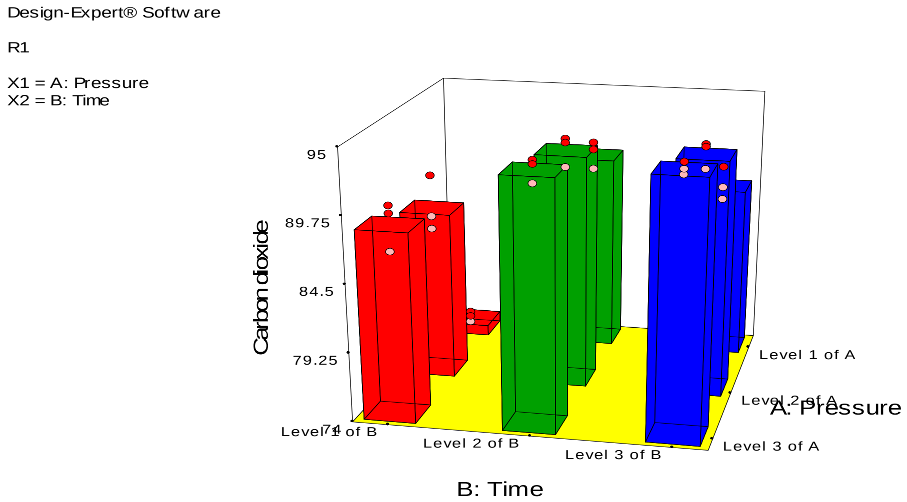


**Figure 4: Effect of Flushing Pressure and the Flushing Time on Retention of $CO_2$ In One Kg Pigeon Pea Packets**

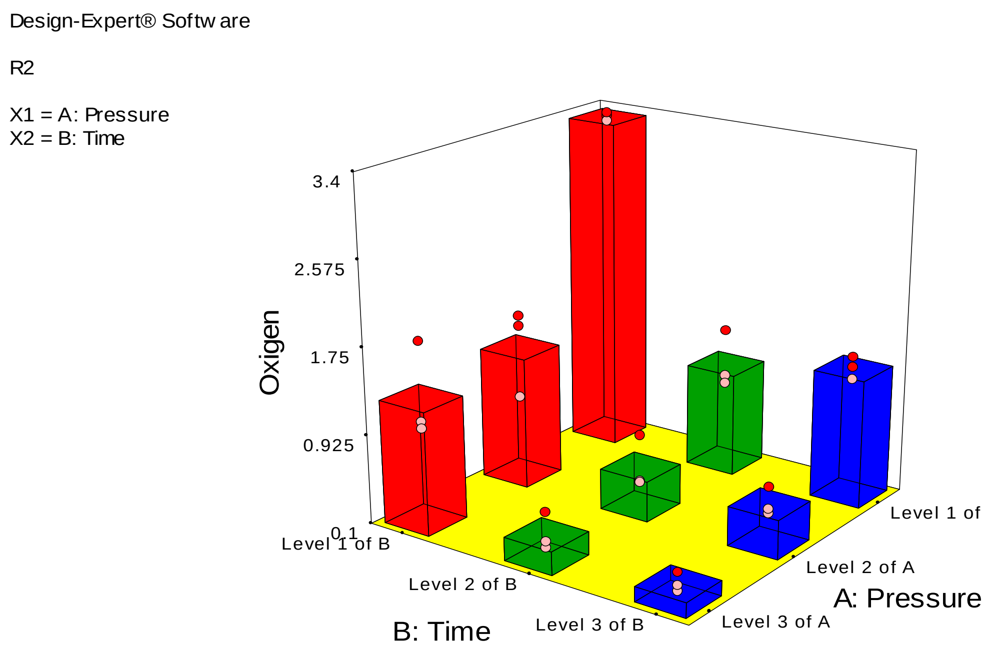


**Figure 5: Effect of Flushing Pressure and the Flushing Time on Retention of $O_2$ in One Kg Pigeon Pea Packets**

**Optimization of Flushing Pressure and Time for Foxtail Millet**

The flushing of carbon dioxide was carried at three different pressure and time intervals. The data recorded for the composition inside the packet are presented in the Table 4.

The data was statistically analyzed and it showed that flushing pressure and time have significant effect on concentration of flushed gas inside the packet. The effect of flushing pressure and time on retention of $CO_2$ and $O_2$ are graphically represented in Figure 5 and Figure 6 respectively. The optimization process was carried out with the optimization tool by fixing the responses R1 ($CO_2$) and R2 ($O_2$) in range. The flushing of $CO_2$ at 3 kg/cm$^2$ pressure for 5 s having 100 per cent desirability was optimized followed by 2 Kg/cm$^2$ pressure with 10 s of flushing gas for one kg foxtail millet retail packets.

**Table 4: Concentrations of $CO_2$ and $O_2$ at Different Flushing Pressure for One kg Foxtail Millet Packet**

| | 2 kg/cm$^2$ | | | | | | 3 kg/cm$^2$ | | | | | | 4 kg/cm$^2$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | | 5 s | | 10 s | | 15 s | |
| | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ | $CO_2$ | $O_2$ |
| 1. | 55.9 | 7.43 | 73.3 | 3.68 | 77.4 | 2.87 | 82.8 | 1.70 | 88.9 | 1.18 | 85.9 | 1.77 | 81.8 | 2.67 | 91.9 | 0.55 | 86.6 | 0.85 |
| 2. | 54.0 | 7.88 | 72.6 | 3.79 | 78.0 | 2.06 | 80.3 | 1.63 | 88.8 | 1.21 | 83.9 | 1.60 | 80.4 | 2.90 | 93.8 | 0.16 | 85.3 | 1.03 |
| 3. | 54.5 | 7.63 | 74.9 | 3.52 | 81.1 | 2.04 | 86.6 | 1.74 | 84.2 | 2.19 | 87.5 | 1.59 | 79.8 | 2.95 | 94.1 | 0.16 | 84.1 | 1.46 |
| Mean | 18.26 | 2.54 | 24.53 | 1.22 | 26.27 | 0.77 | 27.74 | 0.56 | 29.10 | 0.50 | 28.58 | 0.55 | 26.88 | 0.94 | 31.08 | 0.09 | 28.44 | 0.37 |
| CV % | 3.46 | 3.47 | 3.47 | 3.47 | 3.47 | 3.48 | 3.47 | 3.47 | 3.46 | 4.19 | 3.47 | 3.47 | 3.46 | 3.50 | 3.47 | 4.57 | 3.46 | 3.89 |
| CD@1 % | 2.46 | 0.35 | 3.31 | 0.17 | 3.56 | 0.10 | 3.75 | 0.08 | 3.92 | 0.07 | 3.86 | 0.07 | 3.62 | 0.13 | 4.21 | 0.01 | 3.83 | 0.05 |

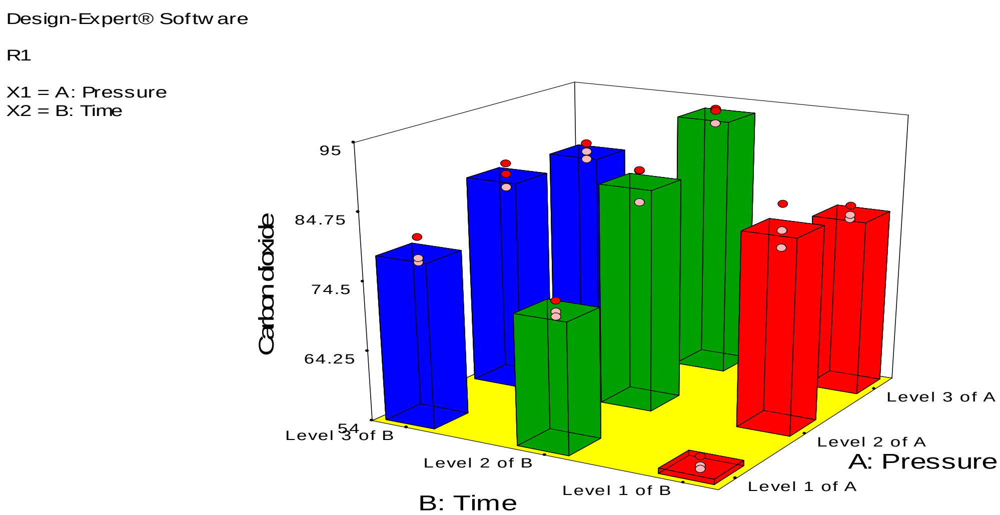


**Figure 6: Effect of Flushing Pressure and the Flushing Time on Retention of $CO_2$ in One Kg Foxtail Millet Packets**

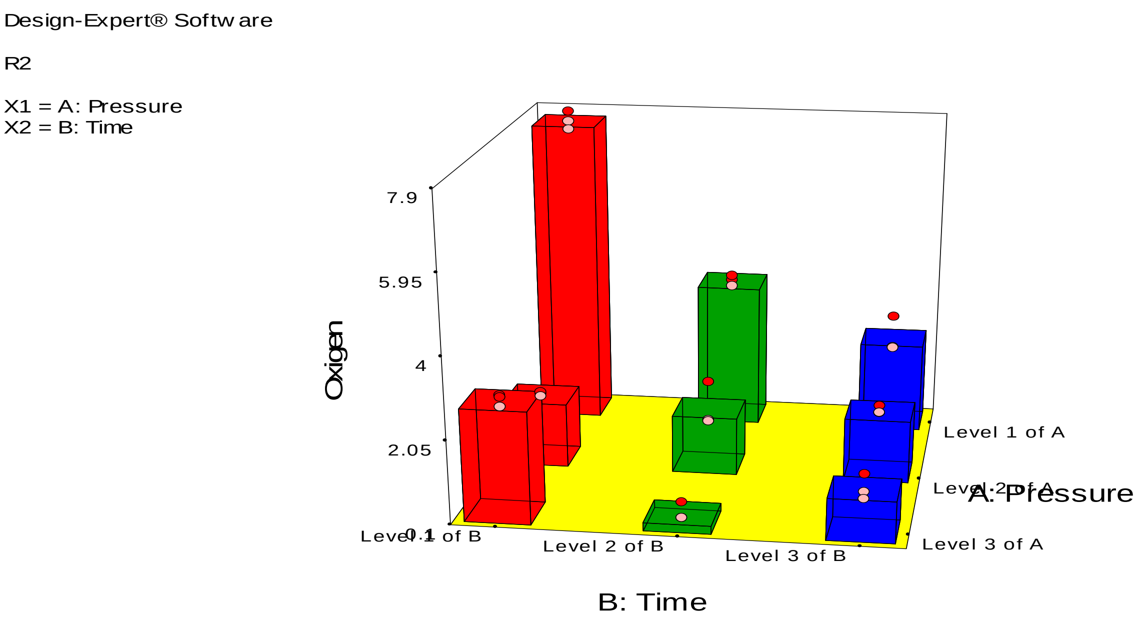


**Figure 7: Effect of Flushing Pressure and the Flushing Time on Retention of $O_2$ in One Kg Foxtail Millet Packets**

**Economics of Developed Unit**

The economic analysis is important part of any technology, since it determines the cost benefit ratio and adoptability of the equipment. The cost of developed modified atmospheric unit was found to be Rs. 8,350.00 and cost of operation of the unit was found to be Rs. 2.00 per packet.

## CONCLUSIONS

The operational parameters of the developed portable modified atmospheric packaging unit *viz.*, flushing pressure and time were optimized for three different grains using the statistical software. The flushing pressure of 3 kg/cm$^2$ and flushing time of 5 s was found to flush maximum percentage of $CO_2$ (89.9%) and minimum percentage of $O_2$ (0.06%) concentrations in the packages of one kg capacity for all the three grains i.e. rice, pigeon pea and foxtail millet. The estimated cost of the developed portable modified atmospheric packaging unit was found to be Rs. 8350.00 and the cost of packaging was about Rs 2.00 per packet of one kg capacity.

***REFERENCES***

1. *Mbata, G. N., Phillips, T. W. and Payton, M. (2004), Mortality of eggs of stored-product insects held under vacuum: effects of pressure, temperature, and exposure time. J. Economic Entomology, 97(2): 695-702.*
2. *Kartikeyan, C., Veeraraghavantham, D., Karpagam, D. and Firdouse, S.A. (2009), Traditional storage practices, Indian J. Traditional Knowledge, 8(4): 564-568.*